

# Supporting children with working memory problems



**Susan Gathercole & Joni Holmes**

Centre for Attention, Learning & Memory

MRC Cognition and Brain Sciences Unit

CALM Workshop, 14<sup>th</sup> March 2014

# Centre for Attention Learning and Memory (CALM)



- Based in the **Cognition & Brain Sciences Unit** (Chaucer Road, Cambridge) funded by the Medical Research Council.
  - Research into human cognition and the brain
- CALM is a new child research clinic, housed in its own building
- Several researchers interested in children's development
  - Professor Susan Gathercole (memory and language)
  - Dr Joni Holmes (memory and learning)
  - Dr Duncan Astle (attention and memory)
  - Dr Tom Manly (attention)
- Current research: attentional disorders including ADHD, working memory problems, language impairments, reading difficulties, dyscalculia, interventions

# Aims of the Centre

- increase our understanding of the cognitive and brain processes involved in learning
- develop ways of identifying and overcoming problems that might emerge during childhood
- provide an information hub for researchers and professionals in children's services



# How it works

- Referrals from children's services (SENCOs, Ed Psychs, SaLTs, CAMHS) for children
  - 6-11yrs (but up to 18 yrs)
  - Problems in reading, maths, language, attention, learning, memory
- 2-hour assessment of cognitive skills (attention, learning, and memory)
- Feedback to referring agents to inform ongoing support



# Procedure for referrals

MRC

Cognition and  
Brain Sciences Unit

1. Referrers identify individuals aged 6-11 who may have problems in:  
**attention, memory, language, reading, and/ or maths**
2. Pass on the Child Information Sheet and Parent Information Sheet to the family
3. Family contacts us. We then contact you for a brief description of the child.
4. Following the assessment at the Centre (15 Chaucer Road), we will send you details of the test results, with an overview
5. After the assessment, families will also be invited to:
  - join the Developmental research Panel (future studies incl. interventions)
  - contribute saliva for later genotyping
  - undergo a structural MRI scan



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# **Introduction to memory and its development**

# Different kinds of memory

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## *Procedural memory*

- Learned skills
- *Lasts for:* lifetime, once skill is established
- *Examples:*
  - handwriting
  - riding a bike

# Different kinds of memory

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## *Semantic memory*

- Facts, knowledge
- *Lasts for:* a lifetime, if used sufficiently frequently
- *Examples:*
  - knowing that Paris is the capital of France
  - knowing the meaning of words

# Different kinds of memory

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## *Autobiographical memory*

- Stored facts and significant events from your life
- *Lasts for:* a lifetime
- *Examples:*
  - first day at school
  - your wedding day

# Different kinds of memory

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## *Episodic memory*

- Records details of particular experiences
- *Lasts for:* up to several days
- *Examples:*
  - Remembering breakfast this morning
  - Where did you park the car?

# Different kinds of memory

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## *Working memory*

- Mental workspace
- *Lasts for:* seconds only
- *Examples:*
  - Following instructions such as “When you pass the church on the left, turn immediately right and take the second left”
  - Mental arithmetic

# Key features of working memory

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- Capacity to hold material in mind and manipulate as necessary for brief period
- Mental workspace
- Limited in capacity
- Catastrophic loss

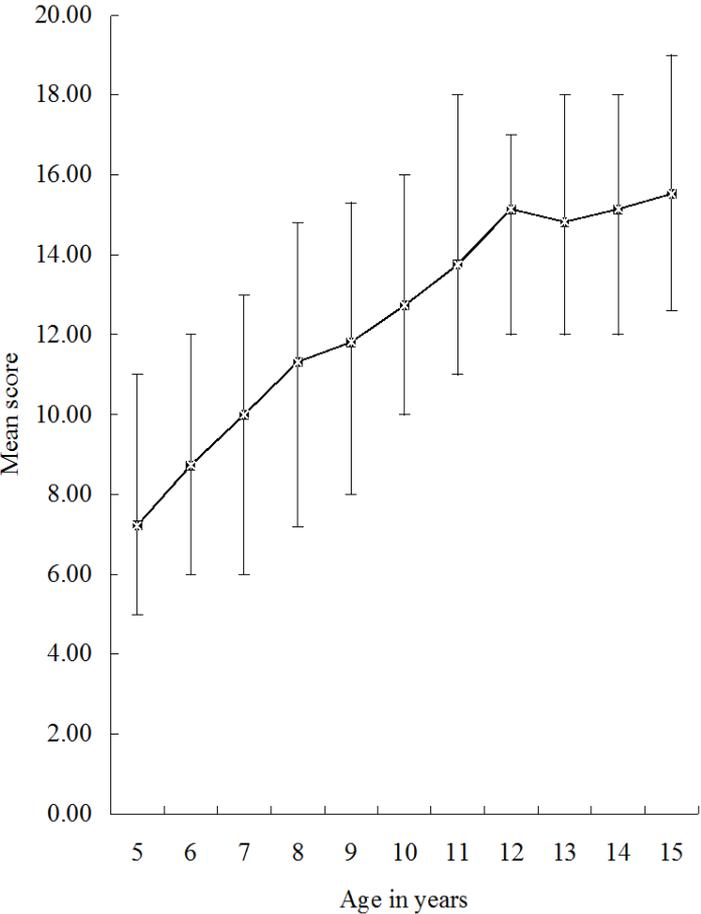
# Development of working memory

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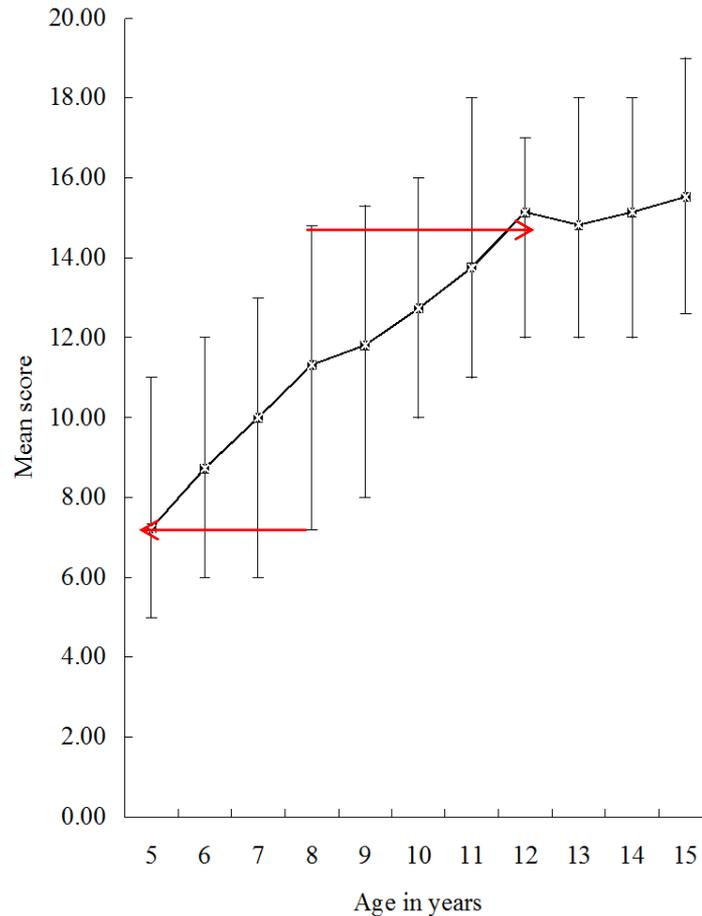
- Working memory ability increases steadily with age between 4 and 14 years
- Large individual variation in ability in children of the same age

# Mean scores on listening recall test from WMTB-C as a function of age, with 10th & 90th centiles bars

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# Mean scores on listening recall test from WMTB-C as a function of age, with 10th & 90th centiles bars



# Breakout 1: What kind of memory?

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*Memory system*

Procedural memory

Semantic memory

Autobiographical memory

Episodic memory

Working memory

# Breakout 1: What kind of memory?

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<i>Memory system</i>	<i>retains ...</i>
Procedural memory	skills
Semantic memory	facts
Autobiographical memory	life knowledge
Episodic memory	specific events
Working memory	recent information

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# What kind of memory?

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- 1. You are given an unfamiliar 7-digit telephone over the phone, but have to find a pen from another room in order to write it down.
- 2. In completing a form, you have to supply your home telephone number.
- 3. Weigh and combine accurately the ingredients ('50g butter, 150g of flour, 75g of sugar, 25g ground almonds') from a recipe that you have just read that is no longer in view.
- 4. Calculate the running total of the cost of items in your shopping trolley, as you add each item.
- 5. Remember a quotation from a Shakespeare play that you studied at school.
- 6. Learn to ride a unicycle.
- 7. Complete the multiplication calculation  $12 \times 9 = ?$
- 8. Attempt the calculation  $124 \times 45 = ?$  without using a pen and paper,
- 9. Remember to attend a doctor's appointment you had booked several days previously.
- 10. Remember where you left your house keys the last time you used them.
- 11. Your friend and you disagree about whether another friend was there at a party a couple of years ago.
- 12. Whistle a tune.
- 13. Amazing luck – there was a question that corresponded directly to some last-minute revision on the morning of the exam.
- 14. Even better – there was also a question on your favourite topic, on which you had done a coursework essay and a short presentation.
- 15. Complete this crossword clue: Tree yielding acorn (3).
- 16. Key your PIN number into an ATM bank machine.
- 17. Re-type a new password that you have just created.

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# Working memory and learning



# Working memory and learning

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WM ability is important because:

- it is closely associated with the ability to learn, and academic attainment
- it does not appear to be affected by experience such as prior education, socio economic status or ethnic group membership.



# Assessing WM at school entry: Gathercole et al. (2003)

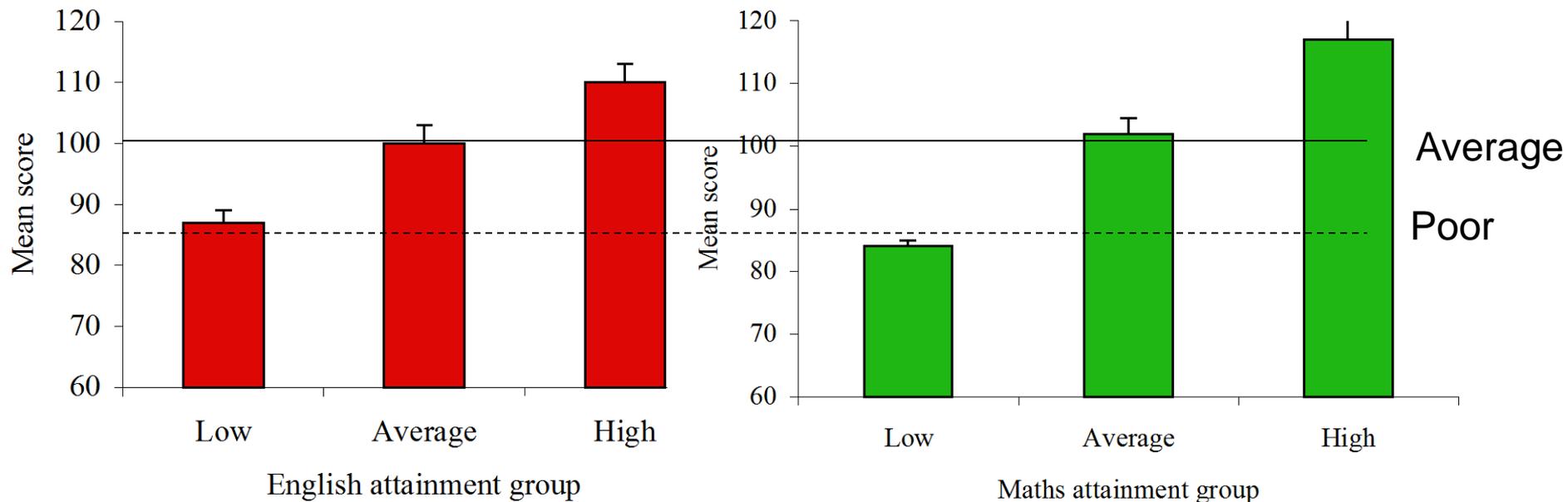
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- Assessed within 6 weeks of school entry at 4 years
- Working memory skills were strongly associated baseline assessments of
  - reading
  - writing
  - mathematics
- Excellent predictors of Key Stage 1 maths and English levels, at 7 years.

Gathercole et al. (2004):

Mean working memory scores as a function of English and maths attainment groups, schools data from 11-year olds

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# Working memory problems in many developmental disorders

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- Reading difficulties/ dyslexia
- Maths difficulties/ dyscalculia
- Specific Language Impairment
- ADHD
- Genetic disorders – Downs, Williams, Fragile X
- Cardiovascular conditions - hypertension

# Characteristics of children with poor working memory

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- Poor academic progress

*More than 80% of children with poor working memory fail to achieve expected levels of attainment in either reading or maths, typically both (Gathercole & Alloway, 2008)*

# Characteristics of children with poor working memory

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- Poor academic progress
- Reserved in groups

*Ross (6 years) is a reserved and quiet child who tends not to volunteer responses and rarely answers direct questions, particularly in the whole-class situation. He is sometimes becomes more vocal when working in small groups although he isn't necessarily discussing the task in hand.*

# Characteristics of children with poor working memory

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- Poor academic progress
- Reserved in groups
- Difficulties in following instructions

*“Put your sheets on the green table, arrow cards in the packet, put your pencil away and come and sit on the carpet.”*

*John (6 years) moved his sheets as requested, but failed to do anything else. When he realized that the rest of the class was seated on the carpet, he went and joined them, leaving his arrow cards and pencil on the table.*

# Characteristics of children with poor working memory

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- Poor academic progress
- Reserved in groups
- Difficulties in following instructions
- Loses track in complex tasks

*When the teacher wrote on the board Monday 11th November and, underneath, The Market, which was the title of the piece of work, Nathan lost his place in the laborious attempt to copy the words down letter by letter, writing moNemarket.*

# Characteristics of children with poor working memory

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# Characteristics of children with poor working memory

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- Poor academic progress
- Reserved in groups
- Difficulties in following instructions
- Problems when activities involve processing and storage

*Ruby's teacher wrote sequences of numbers on the white board that had some numbers missing. She read aloud the numbers, and asked the class what numbers had been missed out. In each case, there was more than one number missing. In each case, Ruby was unable to name the missing numbers.*

# Characteristics of children with poor working memory

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- Poor academic progress
- Reserved in groups
- Difficulties in following instructions
- Problems when activities involve processing and storage
- Place-keeping difficulties

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# Characteristics of children with poor working memory

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- Poor academic progress
- Reserved in groups
- Difficulties in following instructions
- Problems when activities involve processing and storage
- Place-keeping difficulties
- Teachers say: short attention span and highly distractible

*“he’s in a world of his own”*

*“he doesn’t listen to a word I say”*

*“she’s always day-dreaming”*

*“with him, it’s in one ear and out of the other”*

# Distractibility

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*Adam (5 years) struggles to maintain attention, particularly during whole-class teaching when the pupils join together on the carpet. Hence, he sits directly in front of the teacher and is frequently prompted to sit correctly and to pay attention as he regularly fidgets, looks around the classroom and distracts other children near him.*

# ADHD:

## DSM-IV symptoms of *inattention*

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*At least 6 of the following:*

- Often does not give close attention to details or makes careless mistakes in schoolwork, work, or other activities
- Often has trouble keeping attention on tasks or play activities
- Often does not seem to listen when spoken to directly
- Often does not follow instructions and fails to finish schoolwork, chores, or duties in the workplace
- Often has trouble organizing activities
- Often avoids, dislikes, or doesn't want to do things that take a lot of mental effort for a long period of time
- Often loses things needed for tasks and activities
- Is often easily distracted
- Is often forgetful in daily activities

# Symptoms displayed by children with poor working memory

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- Often does not give close attention to details or makes careless mistakes in schoolwork, work, or other activities
- Often has trouble keeping attention on tasks or play activities
- Often does not seem to listen when spoken to directly
- Often does not follow instructions and fails to finish schoolwork, chores, or duties in the workplace
- Often has trouble organizing activities
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*Gathercole & Alloway (2008), Gathercole, Alloway, Elliott, & Kirkwood (2008)*

# Why do these children struggle to learn?

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- Learning is a step-by-step process, based on successes in individual learning activities.
- Children with working memory impairments often fail in the classroom because the working memory loads are excessive for them.
- Working memory failure leads to inattentive behaviour, simply because the child forgets what s/he is doing.

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# **Breakout 2: Identifying children with working memory problems**

# For each child, decide:

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- what (if any) do you consider to be the possible major underlying problems faced by this child?
- whether this child show any of the warning signs associated with working memory impairments? If so, which ones?

# Adam

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Adam is a 10-year old boy. He is viewed by his teacher as experiencing many problems within the classroom, and on occasions can be a disruptive influence due to his high level of distractibility. He often appears restless and fidgety, and on several occasions has broken classroom equipment. His work is of a low average standard, with its quality varying considerably from day to day. His teacher is as yet unsure whether he will attain Level 4 in Key Stage 2 National Curriculum assessments in English, maths and science, although she feels sure that he has the abilities to do so.

# Andrew

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Andrew is a 6-year old boy with a pleasant and cheery personality. He is well-behaved and popular in his class. Andrew's IQ is within the normal range, with a higher Performance IQ (105) than Verbal IQ (95). His academic performance is poor in both numeracy and literacy, and is in the lowest ability group in literacy. He frequently becomes frustrated by the difficulties that he experiences, particularly in writing. Andrew does not often participate in class discussions, and often seems to be unable to respond even after he has raised his hand in response to a question by the teacher at 'carpet time'.

# Olivia

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Olivia is a 7-year old child with an outgoing personality who is well-liked by her classmates. Her IQ is in the high average range (113). She has a mature and responsible attitude and is often chosen by her teacher to run errands. She has been placed in high-ability groups in both literacy and numeracy, and often helps out less able children within the group, occasionally misguiding them. At times she is forgetful, and can appear to be distracted from work by her own thoughts. The teacher often enlists her help in organizing classroom activities such as putting out art materials.

# Alice

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Alice is aged 9 years. She is a timid girl with a close friendship with one other child. She was identified by her school as having special educational needs (School Action stage) one year ago due to her difficulties in developing literacy skills. Despite good comprehension of language, her word recognition skills are very poor and she struggles to extract meaning from text. Her hand-writing is messy, and her spelling is very inaccurate. Alice has made reasonable progress in maths where she copes with the demands of a mid-range ability group.

# Jonathon

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At 8 years, Jonathon struggles to meet the language demands of the classroom despite appearing to be a bright and focused child. His spoken language is not markedly impaired, but is characterized by some degree of phonological immaturity. His progress in reading is very poor and he has struggled with many aspects of maths. In both areas, he receives twice-weekly support from a special needs assistant in school. The severity of his learning difficulties is reflected by his School Action Plus special needs status.

# Charlotte

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Charlotte is a 6-year old girl who has established a small and supportive group of friends in her two years at school. In class activities, however, she often appears withdrawn, and frequently drifts away from activities without completing them. Her teacher says that she often seems to be in a world of her own. She is working in low ability groups in the classroom.

# 5

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One of the lower-ability children in the class has recently completed working memory training, with good results according to the trainer. As yet, you as the class teacher haven't seen any tangible benefits - she is still forgetful and rarely sees activities through to successful completion. What could you do to help her build on her training success on the programme?

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LUNCH

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# Supporting children with working memory problems

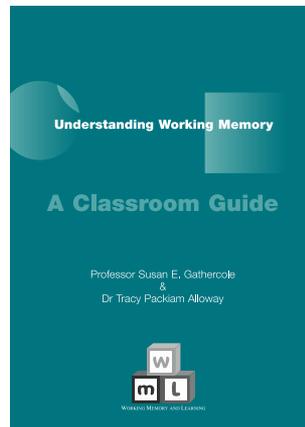
# 1. Classroom support (with J Elliot, Durham)

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Children with poor working memory struggle to learn because of memory overload in activities designed to promote learning.

A priority is therefore to identify children with poor working memory, and minimise learning difficulties by preventing working memory overload.

For more information:



Working Memory & Learning

A Practical Guide for Teachers

Susan E. Gathercole & Tracy Packiam Alloway



# Classroom support: Principles

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- **Be aware of the warning signs of WM failure**
  - Incomplete recall
  - Failing to follow instructions
  - Losing track of place
  - Abandoning the task

# Classroom support: Principles

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- Be aware of the warning signs of working memory failure
- **Reduce amount of information to be stored**

# Examples of heavy WM loads

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- Remembering such sequences as
  - Three or more numbers (e.g., 5, 9, 2, 6)
  - Three or more unrelated words (e.g., *cat, lion, kangaroo*)
- Writing lengthy sentences containing some arbitrary content
  - (e.g., *To blow up parliament, Guy Fawkes had 36 barrels of gunpowder*)
- Following lengthy instructions
  - (e.g., *Put your sheets on the green table, arrow cards in the packet, put your pencil away, and come and sit on the carpet*);
- Keeping track of the place reached in the course of multi-level tasks
  - e.g., writing a sentence either from memory or copying from the board

# Classroom support: Principles

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- Be aware of the warning signs of working memory failure
- Reduce amount of information to be stored
- **Reduce difficulty of processing**

# Classroom support: Principles

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- Be aware of the warning signs of working memory failure
- Reduce amount of information to be stored
- Reduce difficulty of processing
- **Be prepared to re-present important information**

# Classroom support: Principles

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- Be aware of the warning signs of working memory failure
- Reduce amount of information to be stored
- Reduce difficulty of processing
- Be prepared to re-present important information
- **Encourage the use of memory aids**

# Classroom support: Principles

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- Be aware of the warning signs of working memory failure
- Reduce amount of information to be stored
- Reduce difficulty of processing
- Be prepared to re-present important information
- Encourage the use of memory aids
- **Help the child to use strategies**

# What teachers say about the intervention ....

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- “Their self esteem has improved as well because they’re not failing anymore. They are now actually succeeding so self-confidence has hugely improved.”
- “ I find, especially with the ones that struggle more, that they’re quite excited when they remember what they’ve got to do and when they’re working they seem to be enjoying it a lot more.”
- “I am now aware of working memory as a special need and feel increasingly aware of these pupils and the strategies needed to support them. I can now identify pupils with working memory problems myself.”
- “I understand how important it is to repeat information and explain things again and again to these pupils to support them. You can’t simply provide information once and move straight on or expect children to have taken it on board.”
- “We have been discussing whether we need to consider more widely all the other children in the school as well. It’s become a way of teaching for us now more than anything, and we now need to disseminate it to all the other staff so it becomes part of their teaching. We’re hoping to make this quality teaching and a school strategy.”

## 2. WM training

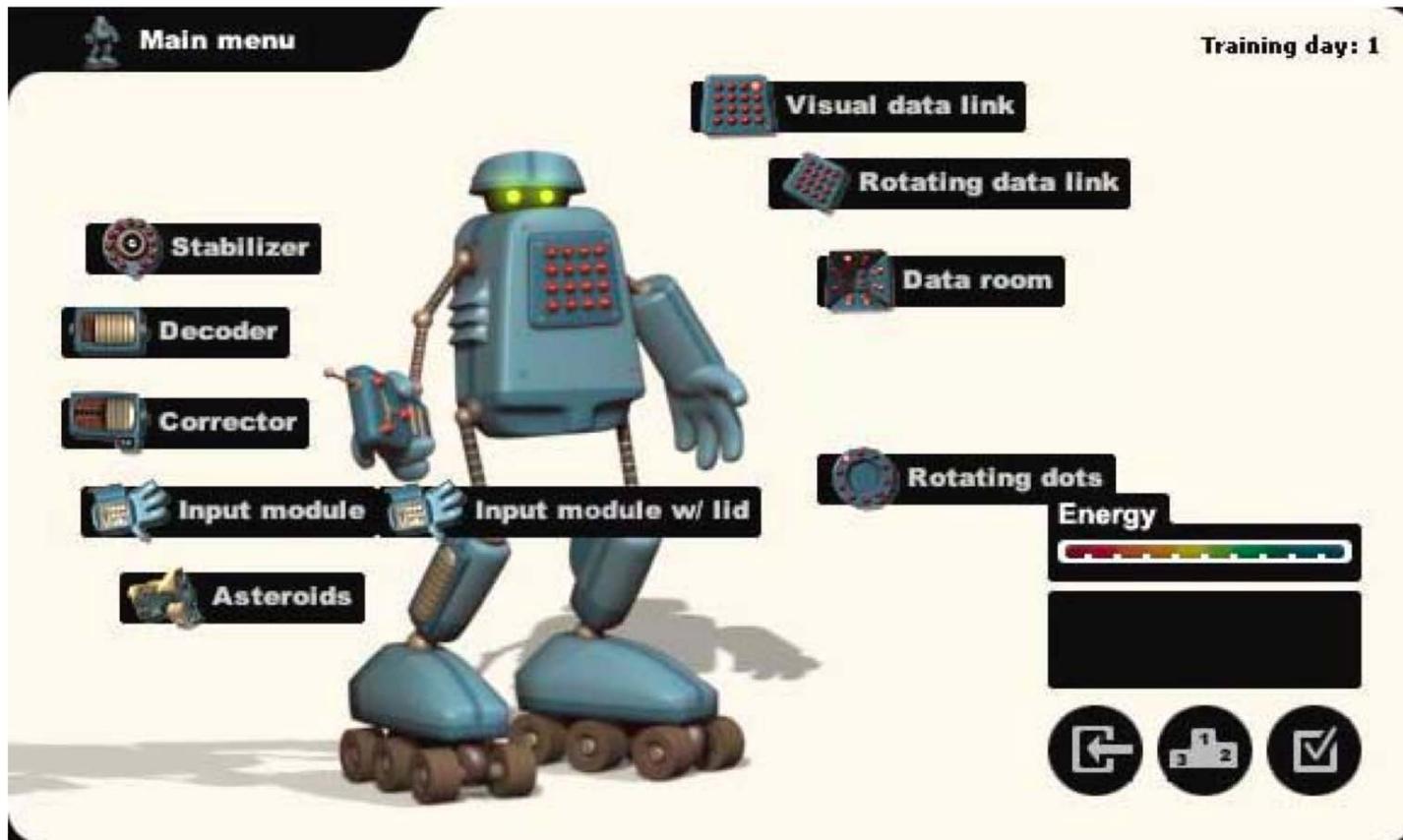
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### Cogmed Working Memory Training – Pearson

- Computerised memory training program
- Game-style environment designed to train working memory
- Train on working memory tasks for 25 sessions over a 6-8 week period
- Adaptive: individual works at span level

## 2. WM training

### Training environment



## 2. WM training

Stills from two training tasks



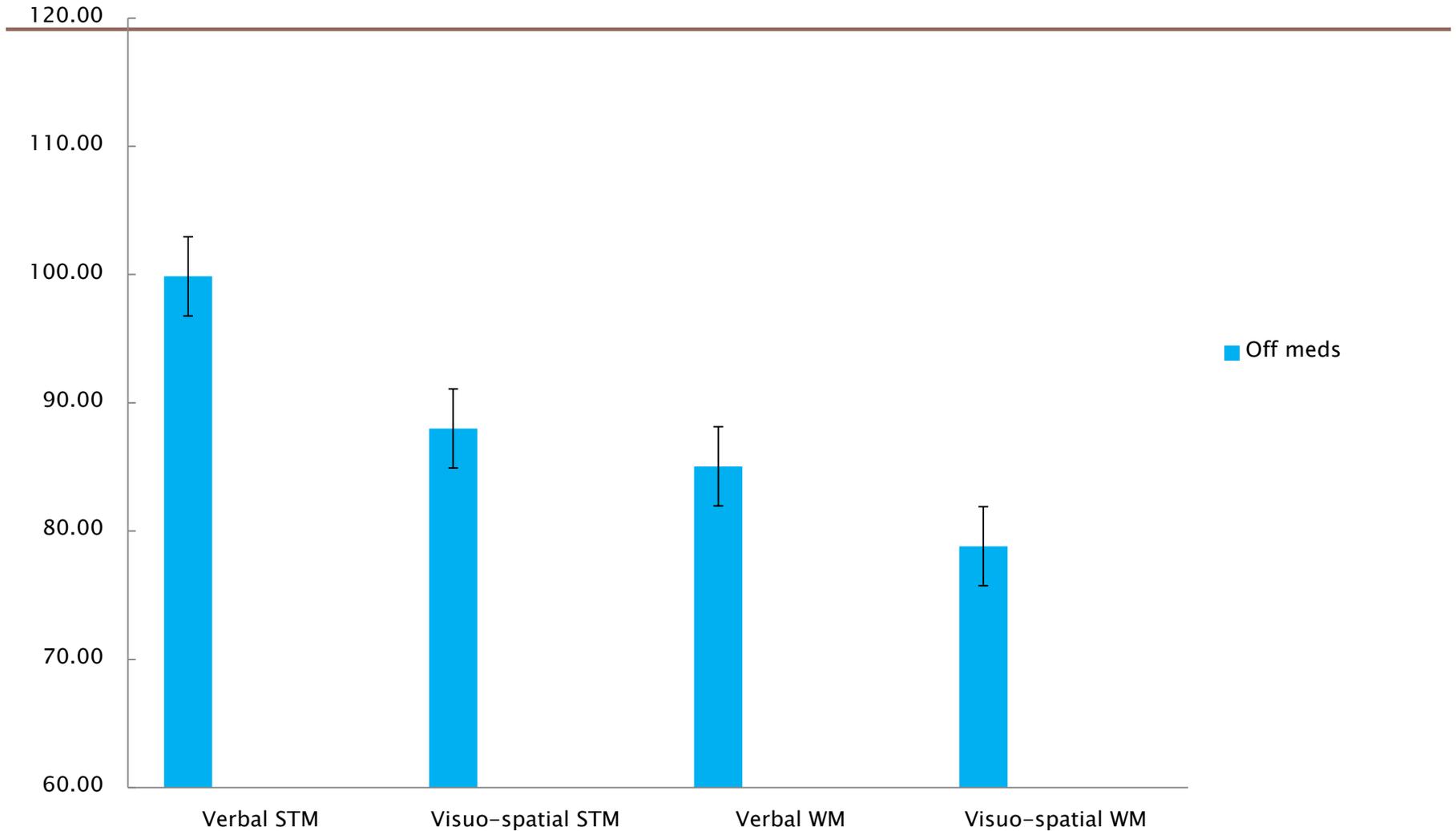
## 2. WM training in children with ADHD

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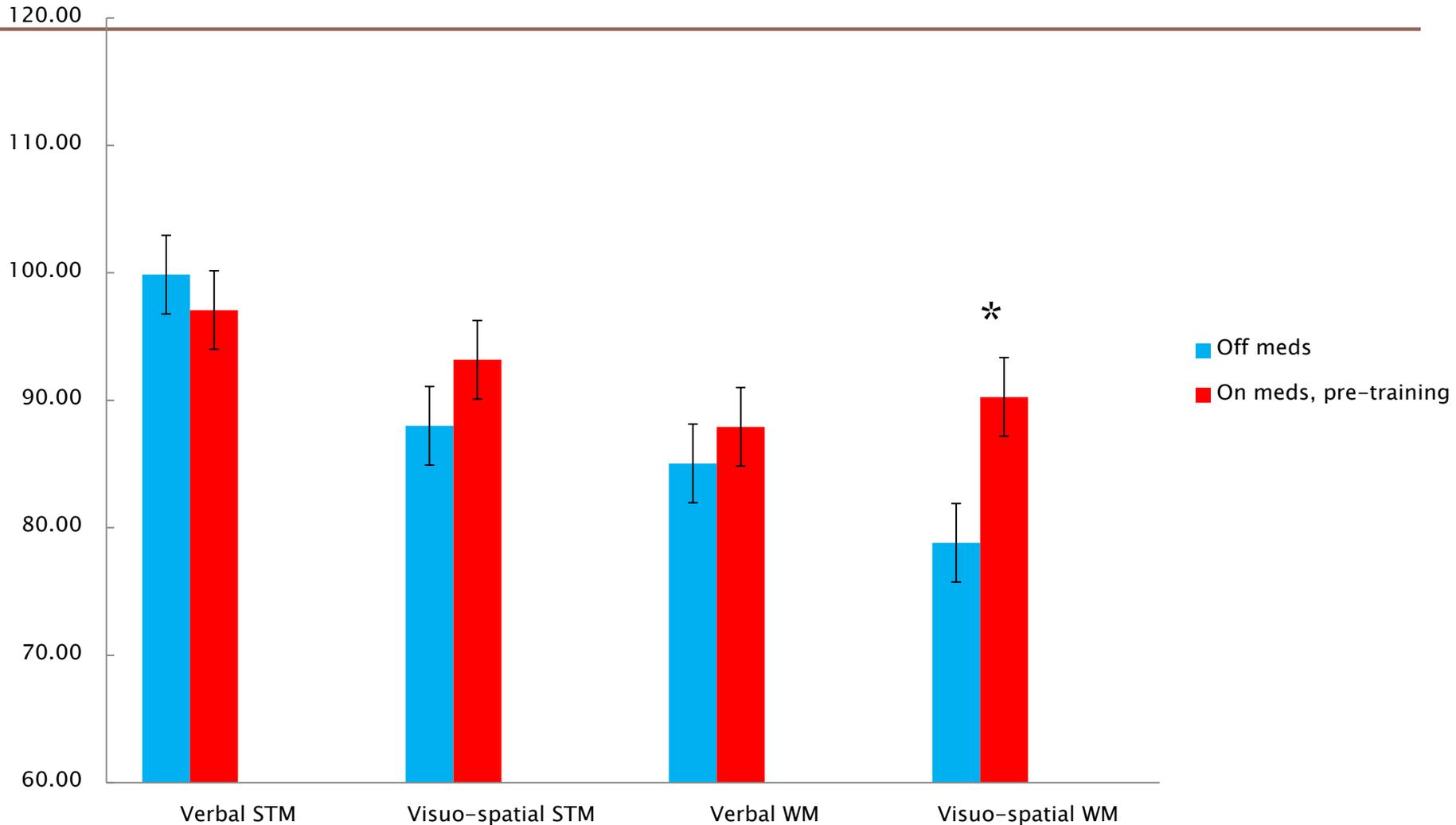
### **Children with ADHD (Holmes et al., 2010)**

- 25 children with clinical diagnosis of ADHD-C
- Assessed off medication, on medication, after training and 6 mth follow up (medicated)
- IQ and WM

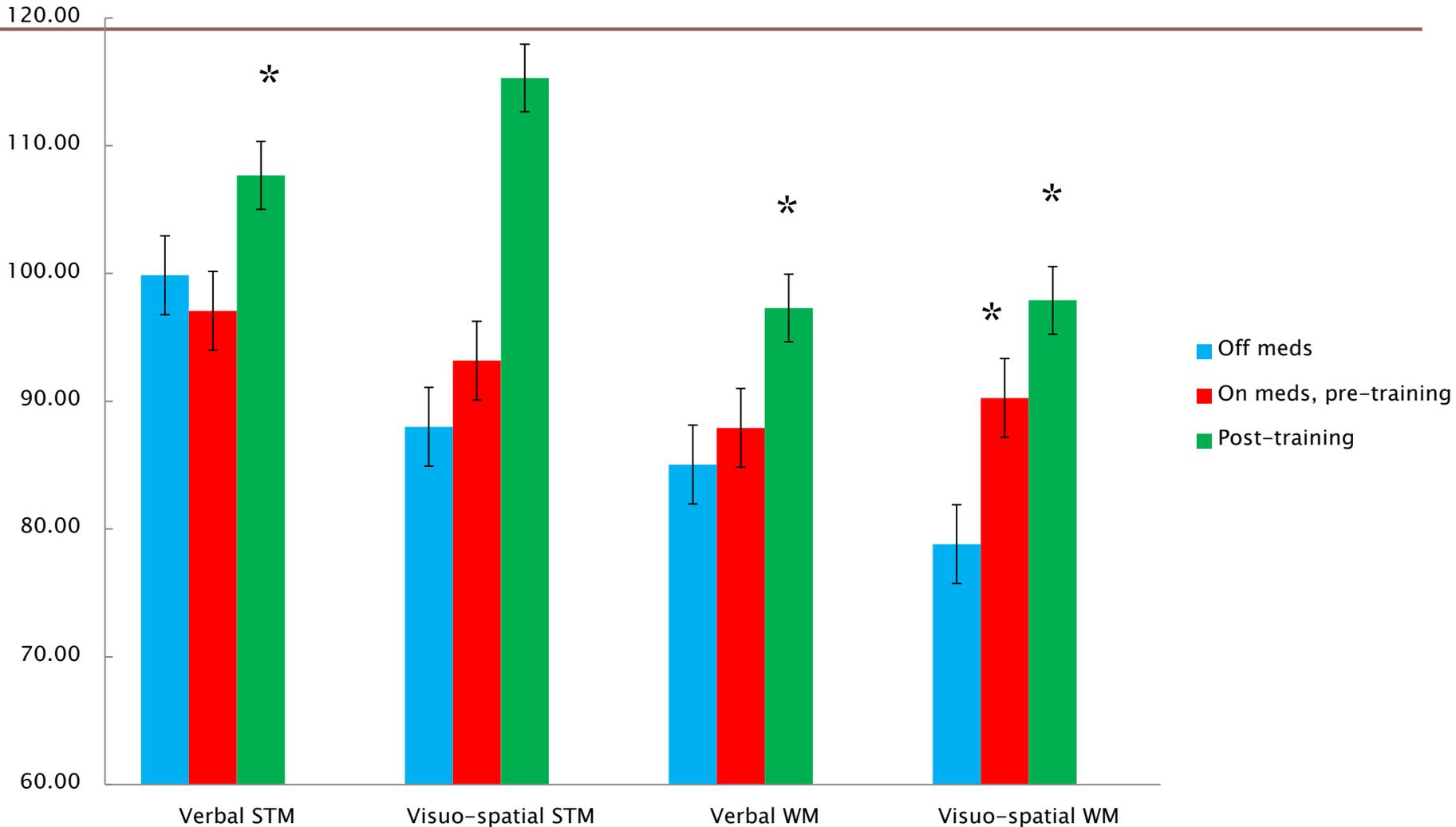
# Training children with ADHD (Holmes, Gathercole, Place, Dunning, Hilton & Elliott, 2010)



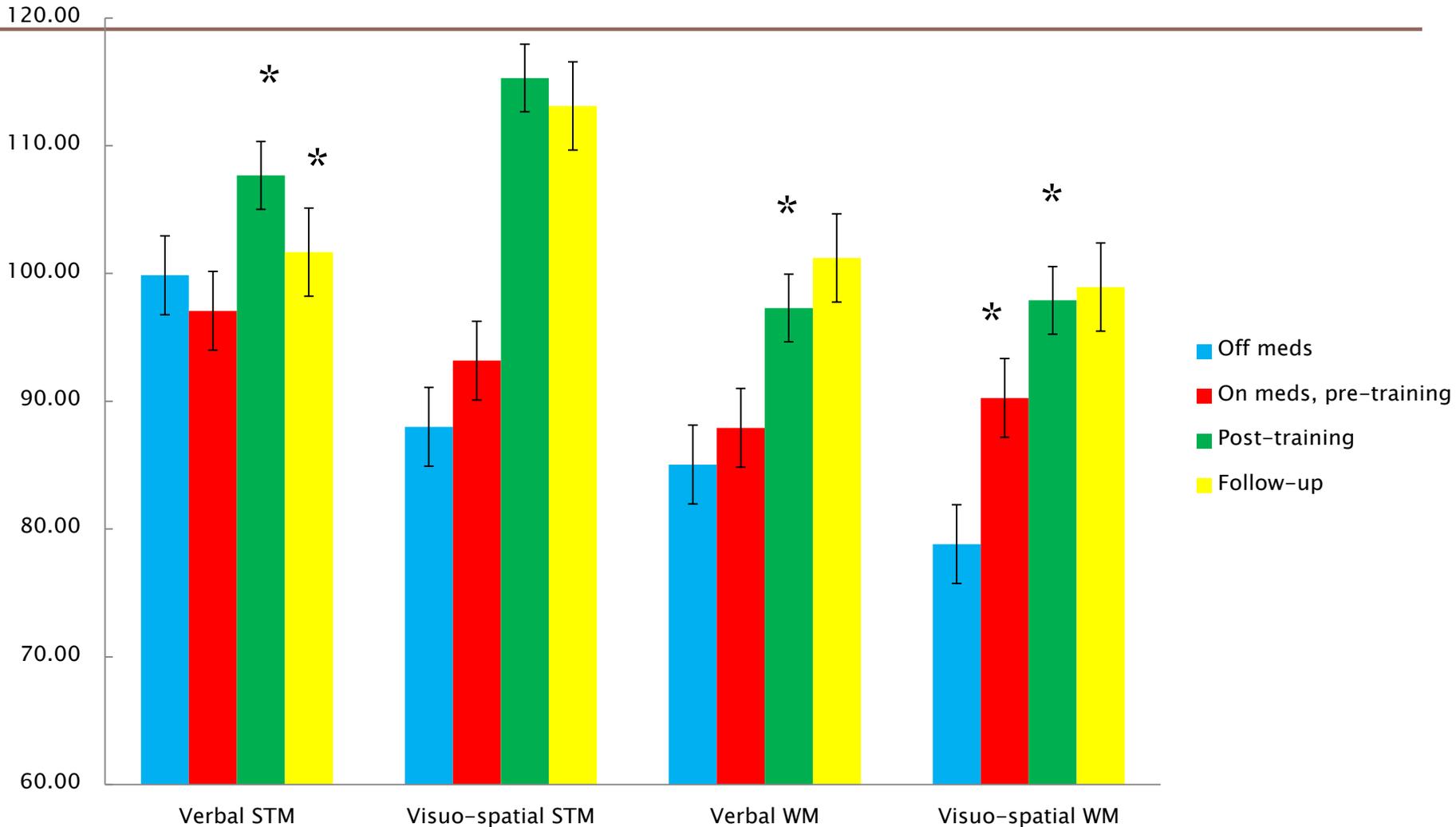
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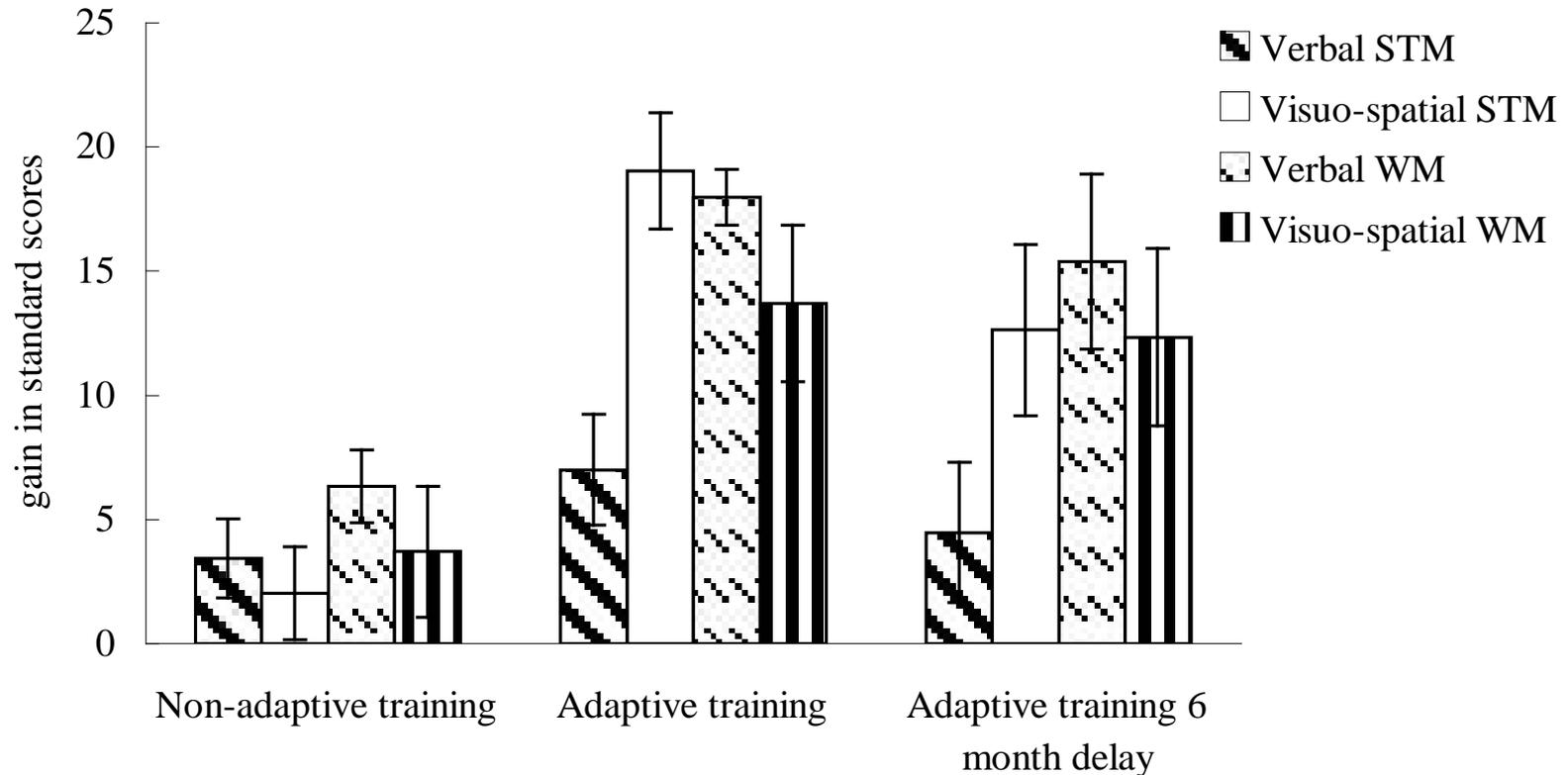
## 2. WM training in children with poor WM

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### Children with poor WM (Holmes et al., 2010)

- 42 children, 8-11 years, with low WM (scores <86 on two verbal WM tasks, bottom 15<sup>th</sup> centile)
- Two groups
  - Adaptive, standard version of training programme
    - training at maximum span level
  - Non-adaptive, control condition
    - training at fixed span level of 2
- Assessed WM, IQ, maths, reading and ability to follow spoken instructions
  - Instruction span: *Touch the blue pencil then pick up the yellow ruler and put it in the red box*

## Training children with poor WM (Holmes, Gathercole & Dunning, 2009)

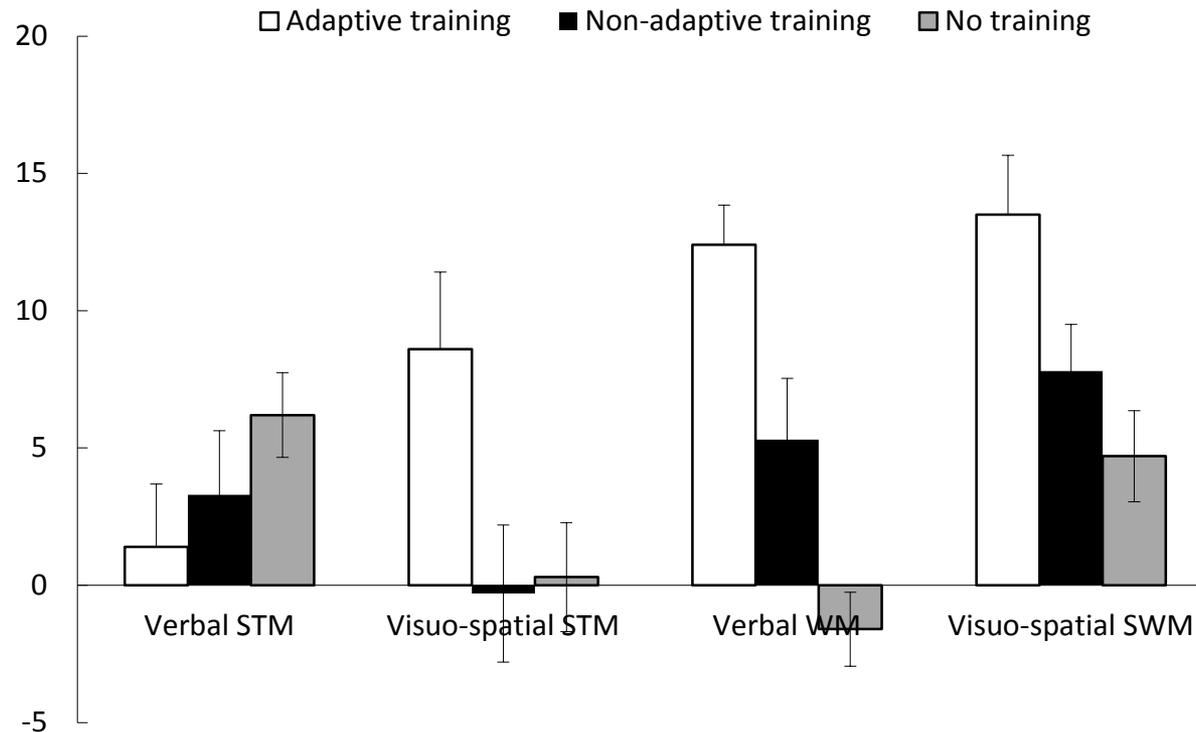


Significant improvement in maths scores for the adaptive group six months after training had ceased

# Training children with poor WM: replication in a large-scale randomised controlled trial

(Dunning, Holmes & Gathercole, 2013)

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Sustained improvements in WM  
No changes in measures of academic ability

## 2. WM training when implemented by schools

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- Evidence that working memory can be improved when researchers run it in schools, but...
- Can training be extended to children at high educational risk, or whole classes, without extensive research support?
- Does training improve academic performance?
- 2 field trials, one with a whole class of children and another with children with low academic performance

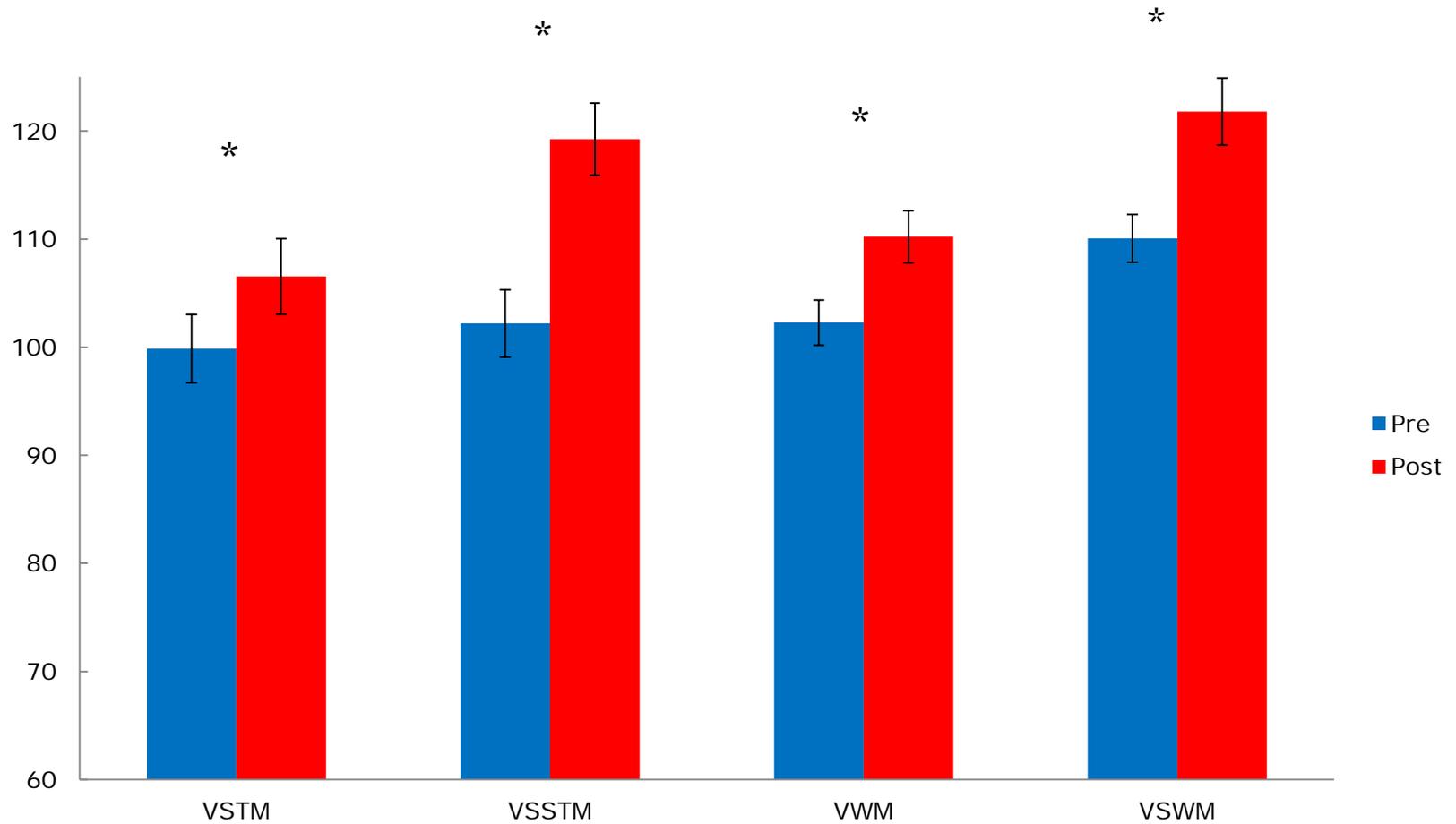
Holmes, J., & Gathercole, S E. (2013). Taking working memory training from the laboratory to schools, in press

# Field Trial 1: Whole class

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- 22 children aged 8/9yrs
- Training in school with a class teacher and classroom assistant, as a single group
- Assessed before and after training on standardised working memory measures by a researcher blind to the intervention

# Field Trial 1: Working Memory



# Field Trial 2: Children with Low Academic Performance

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- 50 children, 9-11 years, with lowest English and maths scores in Teacher Assessments at the end of previous school year
  - 25 Year 5 (9/10), 25 Year 6 (10/11)
  - Completed training in groups in school, supervised by teachers
- Matched on age, gender and Teacher Assessment scores to 50 children from previous Year 5 and Year 6 cohorts who did not undergo training
- Assessed progress across relevant academic year, measured by improvement in National Curriculum sublevels

# Field Trial 2: Children with Low Academic Performance

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*Mean sublevel gains (SDs) in attainment as a function subject and school year*

	Year 5		Year 6	
	Trained Group	Comparison Group	Trained Group	Comparison Group
English	1.48	2.36	2.00	1.12
Maths	1.36	-1.04	2.12	1.32

- Children in Year 6 who received training made significantly greater progress in both English and maths
- In Year 5, trained children made significantly greater progress in maths

# Does WM training 'cure' WM problems?

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- No: training gains are limited to other highly similar tasks
- No benefits for:
  - classroom activities that depend on WM
  - reading, maths
  - behaviour (inattentivity, hyperactivity)although these also depend on WM
- Indicates that the efficiency of WM is not fundamentally changed by training
- Rather, strategies and skills developed that are highly specific to the training activities (Dunning & Holmes, 2014).

# Challenge for practice: How can we make WM training effective?

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## ***Narrow the transfer gap:***

bring the training close to learning by embedding training in educational activities that depend on WM

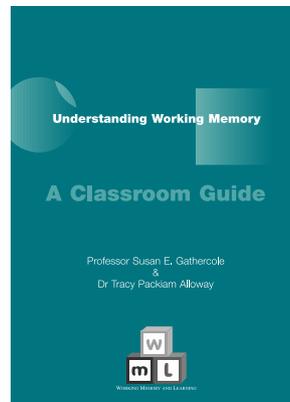
## ***Learn lessons from other fields of rehabilitation:***

extensive practice following training in use of new strategies in everyday activities

# Overview

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- WM problems are common in children with and without diagnosed developmental disorders
- They are closely linked with impairments in learning likely to be caused in part by WM failures in learning activities
- Training and classroom support may be helpful in managing these problems
- An understanding of the consequences of WM failures for classroom functioning is vital



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# **Breakout 3: Classroom challenges**

# Activity

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The following classroom situations may challenge children with poor working memory. Imagine that you are a teacher with such a child in a class that you are teaching. How would you help the child meet the challenges of the following situations?

It's close to the end of the lesson and many of the children still have not completed a maths worksheet activity that has involved manipulating coloured counters. The materials have to be collected together and put away and the worksheets must be returned to each child's maths folder (in their drawer). How would you organise the class (including the child with a working memory problem) in such a way as to achieve this?

The purpose of today's literacy lesson is to develop the children's skills in writing sentences that they have generated for themselves. The sentences should be related to the child's family. What sort of guidance would you offer the child with an impairment of working memory?

# 3

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You are a teacher of a Year 5 class (9/10 years). Some shared classroom materials held currently by Mrs Taylor, a teacher in an adjoining building, are needed urgently in your own classroom. How would you go about giving the responsibility for this errand to a child with poor working memory?

# 4

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A child that you think may have poor working memory is doing nothing despite having received clear instructions about the current lesson activity. What would you do?

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END